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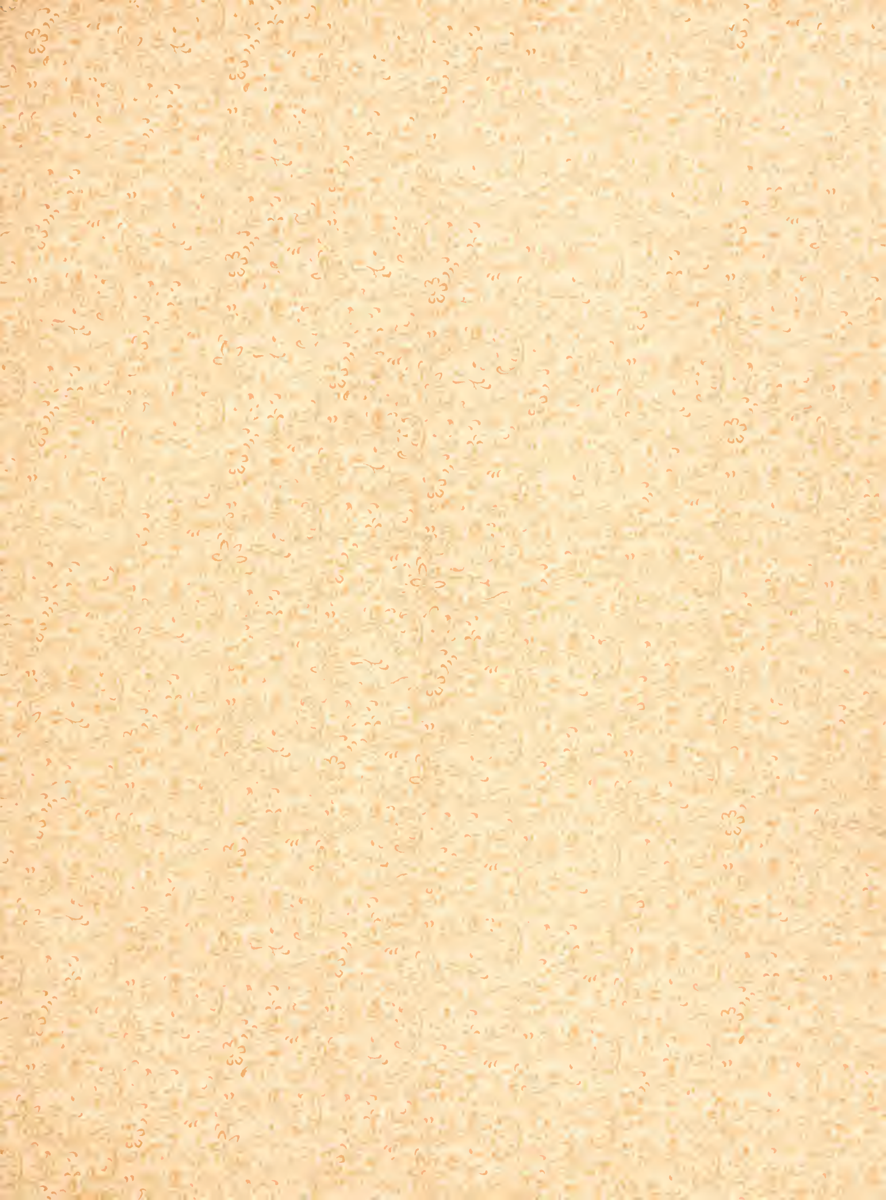

THE OSMOTIC PRESSURE OF MANNITE SOLUTIONS BETWEEN TEN AND FORTY DEGREES.

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DISSERTATION.

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF
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BY
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THE OSMOTIC PRESSURE OF MANNITE SOLUTIONS BETWEEN TEN AND FORTY DEGREES.

INTRODUCTION.

Van't Hoff in his paper "The Role of Osmotic Pressure in the Analogy Between Solutions and Gases" first deduced thermodynamically the relations between the lowering of vapor-pressure and the lowering of the freezing point by dissolved substances and the osmotic pressure of these solutions.[1]

Nernst in his book "Theoretical Chemistry" deduces the following:[2]

Let us take a cylinder containing a solution and the pure solvent which are separated from each other by a semi-permeable partition (allowing free passage to the water but not to the dissolved substance) in the form of a piston. As the piston is raised or lowered water will enter or leave the solution thereby causing a dilution or concentration of the solution. But if we imagine the piston removed the solute will diffuse up into the pure solvent, therefore it necessarily follows that an upward pressure will be exerted on the piston and the greater this pressure is, so much greater is the work which the solute can perform in its expansion: the amount of this work can be calculated from the product of the pressure and the volume through which the piston is displaced.

Now suppose we remove a small quantity of the solvent from the solution by lowering the piston. The expenditure of work necessary for this amounts to Pdv in which dv is the volume through which the

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[1] Zeit. phys. chemie. 1. 498.
[2] Theoretical Chemistry p. 134.

piston is lowered. Let the quantity of solvent removed from the solution be dxg. mol. Now we can also remove the same quantity of solvent from the solution by means of isothermal distillation, and denoting by p and p' the respective vapour tensions of the pure solvent, and of the solution at the temperature T, the expenditure of work necessary is

$$d\ x\ R\ T\ \ln \frac{p}{p'} \qquad (1)$$

Now since the work must be the same in these two isothermal and reversible ways, therefore

$$P\ d\ v = d\ x\ R\ T\ \ln \frac{p}{p'}$$

$$P = \frac{dx}{dv}\ R\ T\ \ln \frac{p}{p'} \qquad (2)$$

Now as the addition of dx mols of the pure solvent to a sufficiently dilute solution produces neither contraction nor dilution, dv is obviously equal to dx mols, therefore

$$d\ v = \frac{M_o}{S}\ d\ x \qquad (3)$$

From (2) and (3)

$$P = \frac{S}{M_o}\ R\ T\ \ln \frac{p}{p'}$$

In order to obtain P in atmospheres we must express volume of one mol of the solvent in litres and must write 0.0821 for R, therefore

$$P = \frac{0.0821\ T\ \ 1000\ S}{M_o}\ \ln \frac{p}{p'}\ \text{atms.} \qquad (4)$$

From this it can be seen that solutions of various substances in the same solvent, when they have the same vapour pressure are isosmotic. "Therefore it follows directly from this that solutions of the solvent which have the same freezing point must have the same osmotic pressure. For as the freezing point is that temperature at which the solid solvent,

ice, and the solution are capable of existing together, it must also be the point at which the curves of the vapour pressures of the solution and of the solid solvent cut each other, where both have the same vapour pressure. For if we suppose, for example, that the vapour pressure of ice and that of the water solution were different at the freezing point, then a process of isothermal distillation would begin, by which equilibrium would be disturbed; equilibrium can only be staple when the vapour of the solvent over the solution and the solid is of the same density. Therefore, solutions of the same freezing point have equal vapour pressures, namely, that of the separated ice and are isotonic." [1]

Now the relation which exists between the lowering of the freezing point and the osmotic pressure of a solution can be deduced by combining the equation for the molecular heat of sublimation with that for the heat of vaporization Λ whence upon integration we get [2]

$$\ln \frac{p}{p'} = \frac{\sigma - \Lambda}{R} \left(\frac{1}{T} - \frac{1}{T_0} \right) \qquad (5)$$

From (4) and (5) we get

$$P = \frac{1000 \; S \cdot w \; t}{24.19 \quad T_0} \text{ atms.} \qquad (6)$$

Where $w = \dfrac{\sigma - \Lambda}{M}$ = heat of fusion of 1 gr. of the solvent expressed in gr. cal.; T_0 = fusing point; S = specific gravity and t denotes $T_0 - T$ the lowering of the freezing point and 24.19 is the factor to reduce cal. to litre atmospheres.

Thus for an aequeous solution we have

$$P = \frac{1000 \times 79.6 \quad t}{24.19 \times 273} = 12.05 \; t \text{ atms.}$$

where t equals $T_0 - T$ the lowering of the freezing point.

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1. Theoretical Chemistry P. 137.
2. Ibid P. 138.

Thus by means of this equation we are able to calculate within a limited range of temperature, which includes the freezing point itself, the osmotic pressure of a solution whose lowering of the freezing point we know.

Let us take for example Cane Sugar and Glucose.

TABLE 1 .

DEPRESSION OF THE FREEZING POINTS OF WEIGHT - NORMAL SOLUTIONS.[1]

CONCENTRATION	CANE SUGAR		GLUCOSE	
	DEPRESSION	MOLECULAR DEPRESSION	DEPRESSION	MOLECULAR DEPRESSION
	degrees	degrees	degrees	degrees
0.1	0.195	1.95	0.192	1.92
0.2	0.393	1.96	0.386	1.92
0.3	0.584	1.95	0.576	1.92
0.4	0.784	1.96	0.762	1.91
0.5	0.983	1.97	0.952	1.91
0.6	1.190	1.98	1.147	1.91
0.7	1.390	1.99	1.337	1.91
0.8	1.621	2.02	1.528	1.91
0.9	1.829	2.03	1.720	1.91
1.0	2.066	2.07	1.918	1.92

[1] THE OSMOTIC PRESSURE OF AEQUEOUS SOLUTIONS
REPORT ON
INVESTIGATIONS MADE IN THE CHEMICAL LABORATORY
OF THE JOHNS HOPKINS UNIVERSITY
DURING THE YEARS 1899 - 1913
BY H. N. MORSE,
CARNEGIE INSTITUTION OF WASHINGTON
PUBLICATION 198.

TABLE II

WEIGHT - NORMAL CONCENTRATION CANE SUGAR.[1]

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Temp.		RATIO OF OSMOTIC TO GAS PRESSURE.								
0°	(1.106)	1.061	1.061	1.060	1.069	1.077	1.083	1.093	1.104	1.115
5°	1.082	1.063	1.058	1.059	1.067	1.074	1.084	1.093	1.102	1.115
10°	1.082	1.060	1.059	1.060	1.066	1.073	1.083	1.092	1.102	1.113
15°	1.082	1.061	1.061	1.059	1.068	1.073	1.083	1.093	1.102	1.115
20°	1.084	1.062	1.060	1.060	1.067	1.073	1.084	1.093	1.103	1.115
25°	1.084	1.059	1.060	1.059	1.065	1.071	1.083	1.093	1.102	1.113
	(1.083)	(1.061)	(1.060)	(1.060)	(1.067)	(1.074)	(1.083)	(1.093)	(1.103)	(1.114)
30°	1.000	1.020	1.031	1.040	1.050	1.060	1.069	1.081	1.089	1.101
40°	1.003	1.011	1.024	1.038	1.046	1.054	1.059	1.067	1.076	1.085
50°	1.000	1.002	1.009	1.017	1.025	1.032	1.041	1.049	1.059	1.071
60°	1.000	1.001	0.999	1.000	1.006	1.015	1.020	1.027	1.033	1.044
70°	.....	.....	.....	.....	1.000	1.002	0.999	1.008	1.015	1.023
80°	.....	.....	.....	.....	.....	.....	.....	1.001	1.000	1.000
90°	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
100°	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Thus from Table II we see that:

(1) In all solutions of cane sugar from 0.1 to 1.0 weight normal, the ratio of the observed osmotic to the estimated gas pressure of the solute is constant for each concentration between 0° and 25°.

(2) This ratio exceeds unity in every instance. This suggests, of course, that the solution has become concentrated through a withdrawal of some of the solvent for the purpose of hydrating the solute.

(3) When the solutions of cane sugar are heated to a temperature above 25°, the ratios of the osmotic to gas pressures, which are all above unity begin to decline. This decrease is relatively more rapid in dilute than in concentrated solutions.

(4) This decline in the ratios which begins at a little above 25°, continues until at some temperature which is characteristic for each concentration it becomes unity, and there is considerable evidence that a ratio having once become unity at some temperature does not further

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1. Carnegie Publication 198.

decline at higher temperatures.

(5) Glucose solutions behave somewhat analogous to cane sugar solutions, as is shown by Table III. At 0° the ratio of osmotic to gas pressure is greater than unity which suggests hydration but this ratio is the same in the case of glucose for all concentrations. At some temperature above 0°, but below 10° this ratio begins to decline. At 10° half the difference between the observed ratio at 0° and unity has disappeared but still the ratio is the same for all concentrations. At 25° and 30° the ratio is unity for all concentrations from 0.1 to 1.0 weight-normal.[1]

TABLE III.

GLUCOSE

WEIGHT - NORMAL CONCENTRATIONS.

	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Temp.	RATIO OF OSMOTIC TO GAS PRESSURE.									
10°	1.035	1.030	1.027	1.030	1.031	1.033	1.033	1.032	1.030	1.031
30°	1.001	1.002	1.000	1.000	1.000	1.001	1.001	1.000	1.002	1.001
40°	1.001	1.001	1.001	0.999	1.000	1.001	1.000	0.999	1.001	1.000
50°	1.000	1.002	1.001	1.000	1.002	1.000	1.000	0.998	0.998	1.000
60°	1.002	.....	0.999	0.998	0.999	.....	.....	.....	.....	.....

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[1] Carnegie Publication 198.

TABLE IV.

OSMOTIC PRESSURES OF CANE SUGAR CALCULATED FROM FREEZING POINTS TABLE I WITH THOSE DIRECTLY DETERMINED.[1]

Conc.	0°		5°		10°		15°		20°		25°	
	Calc.	Det.	Calc.	Det.	Calc.	Det.	Calc.	Det.	Calc.	Det.	Calc.	Det.
0.1	2.35	2.46	2.39	2.45	2.43	2.50	2.48	2.54	2.52	2.59	2.56	2.63
0.2	4.72	4.72	4.81	4.82	4.89	4.89	4.98	4.99	5.06	5.06	5.15	5.15
0.3	7.04	7.09	7.17	7.20	7.30	7.33	7.43	7.48	7.56	7.61	7.69	7.73
0.4	9.44	9.44	9.61	9.61	9.78	9.79	9.95	9.95	10.13	10.14	10.30	10.30
0.5	11.86	11.90	12.08	12.10	12.29	12.30	12.51	12.55	12.73	12.75	12.94	12.94
0.6	14.30	14.38	14.56	14.61	14.82	14.86	15.08	15.14	15.35	15.39	15.61	15.63
0.7	16.77	16.89	17.07	17.21	17.37	17.50	17.69	17.82	17.99	18.13	18.30	18.44
0.8	19.45	19.48	19.81	19.82	20.16	20.16	20.52	20.54	20.88	20.91	21.23	21.25
0.9	21.99	22.13	22.39	22.48	22.80	22.88	23.20	23.21	23.60	23.72	24.01	24.13
1.0	24.91	24.83	25.37	25.28	25.82	25.69	26.28	26.19	26.74	26.64	27.20	27.05

Conc.	30°		40°		50°		60°		70°		80°	
	Calc.	Det.	Calc.	Det.	Calc.	Det.	Calc.	Det.	Calc.	Det.	Calc.	Det.
0.1	2.61	2.47	2.69	2.56	2.78	2.64	2.86	2.72	.....	.....	.....	.....
0.2	5.24	5.04	5.41	5.16	5.58	5.28	5.76	5.44	.....	.....	.....	.....
0.3	7.82	7.65	8.07	7.84	8.33	7.97	8.59	8.14	.....	.....	.....	.....
0.4	10.47	10.30	10.82	10.60	11.17	10.72	11.51	10.87	.....	.....	.....	.....
0.5	13.16	12.98	13.60	13.36	14.03	13.50	14.47	13.66	14.90	13.99	.....	.....
0.6	15.87	15.71	16.40	16.15	16.92	16.32	17.45	16.54	17.91	16.82	.....	.....
0.7	18.61	18.50	19.23	18.93	19.84	19.20	20.46	19.40	21.07	19.57	.....	.....
0.8	21.59	21.38	22.30	21.80	23.02	22.12	23.73	22.33	24.44	22.57	25.16	23.06
0.9	24.41	24.23	25.22	24.74	26.02	25.12	26.83	25.27	27.64	25.56	28.44	25.92
1.0	27.66	27.22	28.57	27.70	29.48	28.21	30.40	28.37	31.31	28.62	32.23	28.82

Thus from Table IV we see that the osmotic pressure of cane sugar solutions up to and including 25° can be calculated from the observed abnormal depressions of the freezing points. But at higher temperatures this can not be done. They can be calculated, then, up to that temperature at which the ratio of osmotic to gas pressures which was constant but abnormally high begins to decline. In other words up to 25° the osmotic pressures as compared with the theoretical gas pressures of the

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[1] Carnegie Publication 198.

solute are abnormal to the same degree as the observed freezing point lowerings as compared with the theoretical lowering but this is not true at higher temperatures. At those temperatures above 25° where the ratio of osmotic to gas pressures becomes constant and unity, we could calculate the osmotic pressure of the solution not from the observed freezing point lowering but from the theoretical depression that is a molecular depression of 1.85°.

In the case of glucose the temperature area over which we can calculate the osmotic pressure from the freezing point lowering is much smaller. In fact only around 0° can it be calculated because somewhere above 0° and below 10° the ratio of osmotic to gas pressure which was constant and abnormally high begins to decline and then at 25° and 30° where the ratio becomes constant and unity the observed lowering of the freezing point no longer can be used in calculating the osmotic pressure of glucose solutions but instead we must make use of the theoretical depression that is a molecular depression of 1.85°.

E. H. Loomis in his work on "The Freezing Points of Aequeous Solutions of Non-Electrolytes"[1] made a careful determination of the molecular depression of 0.1 to 0.5 weight-normal solutions of mannite and found that they were normal 1.85°. Therefore this fact makes the investigation of the osmotic pressure of mannite of especial interest. Substituting in formula 6, we find that the osmotic pressure as calculated from the freezing point lowering is normal, that is equals the gas pressure for 0°. Now from this and the relations which were found to hold between osmotic pressure and lowering of freezing points of glucose and cane sugar solutions, we would say that the ratio of osmotic to gas pressures for mannite solutions would be unity for all temperatures.

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1. Zeit. phys. Chemie. 32 p. 599.

The mannite was obtained from Germany in sufficient quantity and of a degree of purity that no further purification was necessary for its use in this investigation. Unfortunately we were only able to work with 0.1 to 0.5 weight-normal solutions at 10°, 20° and 30° and 0.1 to 0.6 weight-normal solutions at 40° because of the limited solubility of the mannite.

All the solutions used in this investigation were made up on the weight-normal basis, that is by dissolving a gram molecular weight, or decimal part thereof, of the solute in a 1000 grams of water. The true concentration of a solution, wherever the influence of the solvent upon the solute is involved, is determined by the numerical ratio of the molecules of the solute to those of the solvent rather than by the number of solute molecules in a given space. Thus by using the weight-normal basis of making up solutions we always have the same mass of the solvent coming into play no matter what the concentration. Moreover just as we must introduce a correction in the simple equation $p\ v = R\ T$ for gases for the volume occupied by the gaseous molecules which we do by using Van der Waals equation $(p + \frac{a}{v^2})\ (v - b) = K\ T$, so also we must introduce a similar correction in the equation for solutions $p\ (v - b) = K\ T$, in which b expresses the volume occupied by the solute molecules. Suppose we dissolve a gram molecular weight of the solute in water and dilute to a litre. The true volume would be $v - b = 1000$ c.c.— b the volume of the solute molecules. If now, however, we take a gram molecular weight of the solute and dissolve in a 1000 grs. of water, in that mass of the solvent which has the unit volume 1 litre at the temperature of maximum density, and the volume here would be $v \quad b - b = V = 1000$ c.c. Thus by using the weight-normal system of making up solu-

tions, we may be supposed automatically to correct for the b in the equation $p\ (v - b) = K\ T$.

EXPERIMENTAL

CELLS

Of the cells which were used in this investigation on mannite, some were new, that is had never before been set up for any measurement while the others all had been used in measuring osmotic pressure, some with electrolytes, some with non-electrolytes.

The first step to be taken with the finished cell is to expel the air from the pores and to replace it by water. This is accomplished by means of "electrical endosmose", that is, by electrolyzing a dilute solution of lithium sulphate which nearly fills the cell and in which it is immersed to the lower edge of the glazed portion. The lithium ion carries with it the largest atmosphere of water and, therefore, gives a greater endosmose than any other cation. When it is judged that all the air has been removed from the porous wall the cell is removed, rinsed with pure water and allowed to soak for a time in distilled water which is frequently renewed. Finally the electrolysis is repeated the cell this time being filled with distilled water. When the conductivity, after frequent renewals of the water has fallen nearly to that which is normal for distilled water itself the cell is ready for the deposition of the membrane.

Tenth weight-normal solutions of copper sulphate and potassium ferrocyanide are employed, the copper sulphate in which the anode is set being outside the cell and the potassium ferrocyanide together with

the cathode being inside. Thus by means of the electric current the two ions which form the membrane are driven into the cell wall thereby causing the membrane to become firmly packed and embedded in the pore mouths. Due to the fact that the membrane is readily attacked by dilute alkalie, during the deposition the cell is flushed out every two minutes with a fresh solution of potassium ferrocyanide. This membrane-forming process is allowed to run one hour when the cell is removed, rinsed with distilled water and allowed to soak several days in thymol water, when it is again treated as in the first instance. The resistance rises higher and higher on successive treatments until a permanent maximum is reached when the membrane is ready for its first measurement. The new cells were started on June 4, 1913 and on February 4, 1914 were ready to be set up for the measurement of the osmotic pressure of mannite at 10°.

The cells when not in use were allowed to soak in thymol water, in the membrane depositing baths, at the temperature at which they were to be used for measurements and every other day the membrane-forming process was repeated for an hour. After an experiment is finished the cell is emptied, thoroughly washed and allowed to soak in thymol water several days after which it is treated like the other cells.

Of the old cells A_6, I_6, M_6, P_6, U_6 were never used with electrolytes.

C_6, F_6, K_6, N_6, T_6, W_6, Y_6, Z_6, B_6, G_6, H_6, O_6, Q_6, S_6 were all used at some time in the measurement of the osmotic pressure of lithium chloride. Of these fourteen cells the last six B_6 to S_6 had at one time a membrane of nickel ferrocyanide but when work was started on mannite, this membrane was changed to copper ferrocyanide simply by depositing the copper membrane on top of that of nickel.

The effect of exposing a membrane to an electrolyte is to render it sluggish in its action. This is to be seen first in the long time consumed by the cells in coming to equilibruim and secondly in the considerable thermometer effects which are shown in the rather large fluctuations in pressure from day to day.

Another reason for the slowness of the cells in coming to equilibrium might be in the fact that the pores of the cells due to reburning have shrunk in size and consequently the effective area of the membrane has diminished.

Perhaps mannite itself may have a specific action on the membrane tending to retard the passage of solvent through it. In an experiment cell B_6, which with mannite took twenty-six days to come to equilibrium, when afterwards set up with 1.0 weight-normal solution of glucose reached equilibrium on the thirteenth day. But before we can pass a final opinion on this point more experimental work must be done. This question is an important one and will be fully investigated at a later period.

The cells #1, #2, #3, #4, #5, #6 are interesting because they had their old membrane removed and a new one deposited. The old membranes were removed by treating with an alkaline tartrate and then electrolyzing with dilute nitric acid. After this the cells were thoroughly soaked and the new membrane deposited in the usual manner. Usually not much success attends such a process, but here we were successful as is evidenced by Table XII. Not only did cell #5 give a good measurement but it came to equilibrium on the fifteenth day which is quite rapid for mannite.

MANOMETERS

Of the manometers which were used in this work on mannite nothing special need be said in addition to what has been discussed elsewhere.[1] Several manometers which during the summer had been calibrated in the usual way were filled and their volume and capillary depression determined in the fall and thus two new ones were added to our supply to make up for loss which we suffered in consequence of breakage.

One decided improvement, however, should be mentioned and this is a new type cone made entirely of glass which replaces the old cone of brass and Wood's metal. The cone is that part of the manometer which is fastened into the cell by means of a brass collar and nut. The old type brass cone has two holes passing entirely through it, one for the manometer tube and the other for the hollow needle, which is employed for preliminary adjustment of pressure, both of which (the manometer and the needle) are securely fastened in the cone by means of Wood's metal.[2] Now due to the contractions and expansions which this Wood's metal suffers as the cone is used at different temperatures, there is a tendency in some cases for the cone to become leaky around the manometer tube and consequently high pressures cannot be maintained. This necessitates the taking down of the cell and setting up again with a new manometer. This is the only part of the manometer which gives trouble and especially is this liable to happen at higher temperatures.

But with the glass cone all this trouble is obviated. This consists of a short capillary tube and cone made from a single piece of glass.

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1. Carnegie Publication 198.
2. For full description see Ibid 198.

The capillary in the tube continues through the cone while to one side of this a second opening takes the place of the hollow needle of the brass cone. Through this second opening runs a thin brass or platinum rod having a thread at one end and at the other a brass cap which holds a rubber washer in place against the opening at the bottom of the cone. Thus by means of a threaded cap which screws down on the threaded end of this rod, pressure can be brough to bear against the rubber washer thereby effectually closing this second opening through the cone.

This whole arrangement is then fastened into a brass cap which fits the brass collar and nut arrangement by means of which the manometer is fastened into the cell, by litharge glycerine cement. To this cap is fastened a brass tube which fits around the glass capillary tube increasing its strength and thereby preventing the liability of snapping off from the cone when the valuable manometer is sealed on. Altogether it is quite an improvement over the old cones and has given the best results in every instance.

BATHS

In our constant temperature baths we had a large volume of water and air which were kept in constant circulation over first a cooling surface and then a heating surface. The cooling surfaces were coils of pipe through which tap water circulated while the heating surfaces were enclosed incandescent lamps. The baths themselves were maintained in special rooms whose temperature could be regulated so that the daily fluctuations would be very slight. By these means we were able to maintain any temperature at which we were working to within several hundredths of a degree. For a full account and description of the

baths and temperature regulation see Carnegie Publication 198.

In these measurements on mannite we had no means of testing whether the solutions maintained perfectly their concentrations while in the cells. In the case of cane sugar and glucose this could easily be done, because by means of the polariscope slight changes in the concentration of the solutions could be detected and measured. However, now we have an instrument, the "interferometer" made by Zeiss for use with optically inactive substances and when the final measurements are made on mannite use will be made of this. However, even without this proof there is no reason to doubt the present measurements of the osmotic pressure of mannite because surely if there were changes in concentration occurring in the cells the ratio of osmotic to gas pressures would not have been so nearly constant as they were found to be.

The following tables are a brief outline of some of the measurements which I made with the collaboration of Dr. Frazer and for a more complete discussion of the work consult Carnegie Publication 198.

MEASUREMENTS

TABLE V.

0.1 WT. NORMAL SOLUTION AT 10°. CALCULATED GAS PRESSURE, 2.308.

Experiment 1. Cell F-7. Resistance of membrane, 1,100,000 ohms. Manometer, 60. Time setting up cell January 30, 1914. Barometer during final record: Max., 1.009; Min., .995. Initial pressure 3.393. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

83rd day,	3.300 atms.	85th day,	3.317 atms.	87th day,	3.317 atms.
84th "	3.310 "	86th "	3.307 "		

Mean of all daily pressures April 23-27 = 3.310 atms.
Mean barometric pressure April 23 - 27 = 1.003 atms.
Mean osmotic pressure April 23 - 27 = 2.307 atms. *

TABLE VI.

Experiment 2. Cell Z-7. Resistance of membrane 1,100,000 ohms. Manometer, 61. Time setting up cell January 30, 1914. Barometer during final record: Max., 1,000; Min., .972. Initial pressure 3.135. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

30th day,	3.315 atms.	34th day,	3.311 atms.	37th day,	3.309 atms.
31st "	3.308 "	35th "	3.313 "	38th "	3.309 "
32nd "	3.310 "	36th "	3.311 "	39th "	3.311 "
33rd "	3.315 "				

Mean of all daily pressures Feb. 28 - Mar. 9 = 3.311 atms.
Mean barometric pressure Feb. 28 - Mar. 9 = 0.989 atms.
Mean osmotic pressure Feb. 28 - Mar. 9 = 2.322 atms.
Mean osmotic pressure for experiments 1 and 2 = 2.314 atms.
Ratio osmotic to gas pressure = 1.002.

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* This experiment is of especial interest owing to the fact of the long interval of time (83 days) between the setting up and the coming to equilibruim of the cell, nothing similar to this having ever been experienced with either glucose or cane sugar. In the near future a thorough investigation will be carried out to ascertain whether mannite has a retarding effect on the action of the membrane in allowing water to diffuse through.

TABLE VII.

0.2 WT. NORMAL SOLUTION AT 10°. CALCULATED GAS PRESSURE, 4.616.

Experiment 1. Cell D-6. Resistance of membrane, 1,100,000 ohms. Manometer, 44. Time setting up cell January 29, 1914. Barometer during final record: Max., 1.000; Min., .972. Initial pressure 5.685. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

31st	day,	5.621	atms.	35th	day,	5.598	atms.	38th	day,	5.590	atms.
32nd	"	5.596	"	36th	"	5.596	"	39th	"	5.594	"
33rd	"	5.582	"	37th	"	5.613	"	40th	"	5.598	"
34th	"	5.591	"								

Mean of all daily pressures Feb. 28 - Mar. 9 = 5.599 atms.

Mean barometric pressure Feb. 28 - Mar. 9 = 0.989 atms.

Mean osmotic pressure Feb. 28 - Mar. 9 = 4.610 atms.

Ratio osmotic to gas pressure = .998

TABLE VIII.

0.3 WT. NORMAL SOLUTION AT 10°. CALCULATED GAS PRESSURE, 6.925.

Experiment 1. Cell J-6. Resistance of membrane, 1,100,000 ohms. Manometer, 34. Time setting up cell January 29, 1914. Barometer during final record: Max., 1.008; Min., .987. Initial pressure 8.063. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

57th day,	7.958	atms.	61st day,	7.956	atms.	65th day,	7.938	atms.
58th "	7.958	"	62nd "	7.942	"	66th "	7.926	"
59th "	7.962	"	63rd "	7.958	"	67th "	7.928	"
60th "	7.960	"	64th "	7.957	"			

Mean of all daily pressures Mar. 26 - April 6 = 7.949 atms.
Mean barometric pressure Mar. 26 - April 6 = 0.999 atms.
Mean osmotic pressure Mar. 26 - April 6 = 6.950 atms.

TABLE IX.

Experiment 2. Cell P-6. Resistance of membrane 366,666 ohms. Manometer, 32. Time setting up cell March 8, 1914. Barometer during final record: Max., 1.009; Min., .995. Initial pressure 8.768. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

46th day,	7.916	atms.	48th day,	7.944	atms.	50th day,	7.946	atms.
47th "	7.932	"	49th "	7.929	"			

Mean of all daily pressures April 23 - 27 = 7.933 atms.
Mean barometric pressure April 23 - 27 = 1.003 atms.
Mean osmotic pressure April 23 - 27 = 6.930 atms.
Mean osmotic pressure for experiments 1 and 2 = 6.940 atms.
Ratio of osmotic to gas pressure = 1.002.

TABLE X.

0.4 WT. NORMAL SOLUTION AT 10°. CALCULATED GAS PRESSURE, 9.233.

Experiment 1. Cell A-6. Resistance of membrane, 550,000 ohms. Manometer, 32. Time setting up cell January 28, 1914. Barometer during final record: Max., 1.006; Min., .972. Initial pressure 9.759. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

31st day,	10.297 atms.	35th day,	10.198 atms.	39th day,	10.173 atms.
32nd "	10.229 "	36th "	10.155 "	40th "	10.179 "
33rd "	10.160 "	37th "	10.175 "	41st "	10.206 "
34th "	10.156 "	38th "	10.186 "		

Mean of all daily pressures Feb. 27 - Mar. 9 - 10.192 atms.
Mean barometric pressure Feb. 27 - Mar. 9 - 0.991 atms.
Mean osmotic pressure Feb. 27 - Mar. 9 - 9.201 atms.

TABLE XI.

Experiment 2. Cell U-6. Resistance of membrane 550,000 ohms. Manometer, 37. Time setting up cell January 28, 1914. Barometer during final record: Max., 1.008; Min., .972. Initial pressure 10.025. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

30th day,	10.318 atms.	34th day,	10.159 atms.	38th day,	10.202 atms.
31st "	10,336 "	35th "	10.195 "	39th "	10.169 "
32nd "	10.207 "	36th "	10.188 "	40th "	10.173 "
33rd "	10.148 "	37th "	10.188 "	41st "	10.209 "

Mean of all daily pressures Feb. 26 - Mar. 9 - 10.208 atms.
Mean barometric pressure Feb. 26 - Mar. 9 - 0.992 atms.
Mean osmotic pressure Feb. 26 - Mar 9 - 9.216 atms.
Mean osmotic pressure for experiments 1 and 2 - 9.208 atms.
Ratio of osmotic to gas pressure - .997.

TABLE XII.

0.5 WT. NORMAL SOLUTION AT 10°. CALCULATED GAS PRESSURE, 11.541.

Experiment 1. Cell #5. Resistance of membrane, 1,100,000 ohms. Manometer, 35. Time setting up cell March 1, 1914. Barometer during final record: Max., 1.015; Min., .983. Initial pressure 12.426. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

15th	day,	12.622 atms.	19th	day,	12.600 atms.	22nd	day,	12.627 atms.
16th	"	12.615 "	20th	"	12.626 "	23rd	"	12.612 "
17th	"	12.600 "	21st	"	12.635 "	24th	"	12.622 "
18th	"	12.587 "						

Mean of all daily pressures Mar. 15 - 24 - 12.614 atms.

Mean barometric pressure Mar. 15 - 24 - 1.002 atms.

Mean osmotic pressure Mar. 15 - 24 - 11.612 atms.

Ratio osmotic to gas pressure - 1.006.

TABLE XIII.

0.1 WT. NORMAL SOLUTION AT 20°. CALCULATED GAS PRESSURE, 2.390.

Experiment 1. Cell U-6. Resistance of membrane, 366,666 ohms. Manometer, 61. Time setting up cell December 17, 1913. Barometer during final record: Max., 1.017; Min., .978. Initial pressure 3.443. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

20th	day,	3.406	atms.	24th	day,	3.376	atms.	28th	day,	3.388	atms.
21st	"	3.400	"	25th	"	3.376	"	29th	"	3.389	"
22nd	"	3.396	"	26th	"	3.380	"	30th	"	3.384	"
23rd	"	3.377	"	27th	"	3.380	"				

Mean of all daily pressures Jan. 5 - 15 - 3.387 atms.
Mean barometric pressure Jan. 5 - 15 - 0.996 atms.
Mean osmotic pressure Jan. 5 - 15 - 2.391 atms.

TABLE XIV.

Experiment 2. Cell I-6. Resistance of membrane, 157.142 ohms. Manometer, 61. Time setting up cell January 15, 1914. Barometer during final record: Max., 1.008; Min., .982. Initial pressure 3.386. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

2nd	day,	3.386	atms.	5th	day,	3.416	atms.	8th	day,	3.358	atms.
3rd	"	3.367	"	6th	"	3.395	"	9th	"	3.399	"
4th	"	3.446	"	7th	"	3.373	"	10th	"	3.386	"

Mean of all daily pressures Jan. 16 - 24 - 3.391 atms.
Mean barometric pressure Jan. 16 - 24 - 0.994 atms.
Mean osmotic pressure Jan. 16 - 24 - 2.397 atms.
Mean osmotic pressure for experiments 1 and 2 - 2.394 atms.
Ratio of osmotic to gas pressure - 1.001.

TABLE XV.

0.2 WT. NORMAL SOLUTION AT 20°. CALCULATED GAS PRESSURE, 4.780.

Experiment 1. Cell M-6. Resistance of membrane, 550,000 ohms. Manometer, 34. Time setting up cell December 17, 1913. Barometer during final record: Max., 1.005; Min., .978. Initial pressure 5.866. Observed mean daily total pressures after cell became constant.

FINAL RECORD

14th day,	5.822	atms.	18th day,	5.769	atms.	22nd day,	5.746	atms.
15th "	5.806	"	19th "	5.759	"	23rd "	5.764	"
16th "	5.797	"	20th "	5.756	"	24th "	5.754	"
17th "	5.780	"	21st "	5.743	"			

Mean of all daily pressures Dec. 30 - Jan. 9 - 5.722 atms.
Mean barometric pressure Dec. 30 - Jan. 9 - 0.994 atms.
Mean osmotic pressure Dec. 30 - Jan. 9 - 4.778 atms.

TABLE XVI.

Experiment 2. Cell P-6. Resistance of membrane 366,666 ohms. Manometer, 34. Time setting up cell January 9, 1914. Barometer during final record: Max., 1.017; Min., .982. Initial pressure 5.908. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

4th day,	5.812	atms.	8th day,	5.766	atms.	12th day,	5.774	atms.
5th "	5.801	"	9th "	5.757	"	13th "	5.764	"
6th "	5.792	"	10th "	5.782	"	14th "	5.765	"
7th "	5.781	"	11th "	5.786	"			

Mean of all daily pressures Jan. 12 - 22 - 5.780 atms.
Mean barometric pressure Jan. 12 - 22 - 0.997 atms.
Mean osmotic pressure Jan. 12 - 22 - 4.783 atms.
Mean osmotic pressure for experiments 1 and 2 - 4.780 atms.
Ratio of osmotic to gas pressure - 1.000.

TABLE XVII.

0.3 WT. NORMAL SOLUTION AT 20°. CALCULATED GAS PRESSURE, 7.170.

Experiment 1. Cell O-6. Resistance of membrane, 366,666 ohms. Manometer, 32. Time setting up cell November 29, 1913. Barometer during final record: Max., 1.009; Min., .981. Initial pressure 8.584. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

30th day,	8.288 atms.	34th day,	8.156 atms.	37th day,	8.147 atms.
31st "	8.170 "	35th "	8.152 "	38th "	8.140 "
32nd "	8.175 "	36th "	8.150 "	39th "	8.128 "
33rd "	8.167 "				

Mean of all daily pressures Dec. 28 - Jan. 6 - 8.167 atms.
Mean barometric pressure Dec. 28 - Jan. 6 - 0.998 atms.
Mean osmotic pressure Dec. 28 - Jan. 6 - 7.169 atms.

TABLE XVIII.

Experiment 2. Cell G-6. Resistance of membrane 275,000 ohms. Manometer, 35. Time setting up cell November 29, 1913. Barometer during final record: Max., 1.007; Min., .992. Initial pressure 7.743. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

18th day,	8.235 atms.	22nd day,	8.168 atms.	25th day,	8.212 atms.
19th "	8.195 "	23rd "	8.144 "	26th "	8.221 "
20th "	8.132 "	24th "	8.209 "	27th "	8.184 "
21st "	8.222 "				

Mean of all daily pressures Dec. 16 - 25 - 8.192 atms.
Mean barometric pressure Dec. 16 - 25 - 0.999 atms.
Mean osmotic pressure Dec. 16 - 25 - 7.193 atms.
Mean osmotic pressure for experiments 1 and 2 - 7.181 atms.
Ratio of osmotic to gas pressure - 1.001.

TABLE XIX.

0.4 WT. NORMAL SOLUTION AT 20°. CALCULATED GAS PRESSURE, 9.560.

Experiment 1. Cell G-6. Resistance of membrane, 550,000 ohms. Manometer, 34. Time setting up cell October 30, 1913. Barometer during final record: Max., 1.011; Min., .984. Initial pressure 11.378. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

12th day,	10.634 atms.	16th day,	10.597 atms.	20th day,	10.594 atms.
13th "	10.661 "	17th "	10.578 "	21st "	10.630 "
14th "	10.638 "	18th "	10.575 "	22nd "	10.639 "
15th "	10.624 "	19th "	10.553 "	23rd "	10.647 "

Mean of all daily pressures Nov. 10 - 21 - 10.614 atms.
Mean barometric pressure Nov. 10 - 21 - 1.001 atms.
Mean osmotic pressure Nov. 10 - 21 - 9.613 atms.

TABLE XX.

Experiment 2. Cell Q-6. Resistance of membrane 550,000 ohms. Manometer, 41. Time setting up cell December 3, 1913. Barometer during final record: Max., 1.011; Min., .985. Initial pressure 9.171. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

5th day,	10.571 atms.	9th day,	10.550 atms.	12th day,	10.598 atms.
6th "	10.541 "	10th "	10.546 "	13th "	10.616 "
7th "	10.545 "	11th "	10.578 "	14th "	10.634 "
8th "	10.551 "				

Mean of all daily pressures Dec. 7 - 16 - 10.573 atms.
Mean barometric pressure Dec. 7 - 16 - 1.001 atms.
Mean osmotic pressure Dec. 7 - 16 - 9.572 atms.

TABLE XXI.

Experiment 3. Cell H-6. Resistance of membrane, 366,666 ohms. Manometer, 40. Time setting up cell December 2, 1913. Barometer during final record: Max., 1.005; Min., .982. Initial pressure 8.464. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

28th	day,	10.451	atms.	32nd	day,	10.539	atms.	35th	day,	10.542	atms.
29th	"	10.483	"	33rd	"	10.537	"	36th	"	10.546	"
30th	"	10.509	"	34th	"	10.544	"	37th	"	10.549	"
31st	"	10.513	"								

Mean of all daily pressures Dec. 29 - Jan. 7 - 10.521 atms.

Mean barometric pressure Dec. 29 - Jan. 7 - 0.997 atms.

Mean osmotic pressure Dec. 29 - Jan. 7 - 9.524 atms.

Mean osmotic pressure for experiments 1 and 2 - 9.569 atms.

Ratio of osmotic to gas pressure - 1.001.

TABLE XXII.

0.5 WT. NORMAL SOLUTION AT 20°. CALCULATED GAS PRESSURE, 11.950.

Experiment 1. Cell 0-6. Resistance of membrane, 1,100,000 ohms. Manometer, 35. Time setting up cell October 29, 1913. Barometer during final record: Max., 1.011; Min., .965. Initial pressure 11.652. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

12th day,	12.944 atms.	17th day,	12.956 atms.	21st day,	12.911 atms.
13th "	12.945 "	18th "	12.897 "	22nd "	12.946 "
14th "	12.916 "	19th "	12.892 "	23rd "	12.963 "
15th "	12.921 "	20th "	12.873 "	24th "	12.971 "
16th "	12.910 "				

Mean of all daily pressures Nov. 9 - 21 - 12.927 atms.
Mean barometric pressure Nov. 9 - 21 - 0.998 atms.
Mean osmotic pressure Nov. 9 - 21 - 11.929 atms.

TABLE XXIII.

Experiment 2. Cell S-6. Resistance of membrane, 366,666 ohms. Manometer, 36. Time setting up cell November 17, 1913. Barometer during final record: Max., 1.013; Min., .985. Initial pressure 14.671. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

14th day,	13.017 atms.	18th day,	12.990 atms.	21st day,	12.980 atms.
15th "	12.989 "	19th "	12.995 "	22nd "	12.965 "
16th "	13.002 "	20th "	13.007 "	23rd "	12.983 "
17th "	12.993 "				

Mean of all daily pressures Nov. 30 - Dec. 9 - 12.992 atms.
Mean barometric pressure Nov. 30 - Dec. 9 - 1.001 atms.
Mean osmotic pressure Nov. 30 - Dec. 9 - 11.991 atms.
Mean osmotic pressure for experiments 1 and 2 - 11.960 atms.
Ratio of osmotic to gas pressure - 1.001.

TABLE XXIV.

0.1 WT. NORMAL SOLUTION AT 30°. CALCULATED GAS PRESSURE, 2.472.

Experiment 1. Cell O-6. Resistance of membrane, 550,000 ohms. Manometer, 11. Time setting up cell March 17, 1913. Barometer during final record: Max., 1.014; Min., .997. Initial pressure 3.736. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

17th day,	3.530 atms.	21st day,	3.476 atms.	25th day,	3.461 atms.
18th "	3.519 "	22nd "	3.470 "	26th "	3.455 "
19th "	3.531 "	23rd "	3.468 "	27th "	3.450 "
20th "	3.499 "	24th "	3.465 "		

Mean of all daily pressures April 2 - 12 - 3.484 atms.
Mean barometric pressure April 2 - 12 - 1.005 atms.
Mean osmotic pressure April 2- 12 - 2.479 atms.

TABLE XXV.

Experiment 2. Cell Q-6. Resistance of membrane, 366,666 ohms. Manometer, 9. Time setting up cell April 30, 1913. Barometer during final record: Max., 1.004; Min., .990. Initial pressure 3.790. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

20th day,	3.415 atms.	23rd day,	3.481 atms.	26th day,	3.467 atms.
21st "	3.422 "	24th "	3.431 "	27th "	3.438 "
22nd "	3.414 "	25th "	3.512 "	28th "	3.507 "

Mean of all daily pressures May 19 - 28 - 3.454 atms.
Mean barometric pressure May 19 - 28 - 0.996 atms.
Mean osmotic pressure May 19 - 28 - 2.458 atms.
Mean osmotic pressure for experiments 1 and 2 - 2.469 atms.
Ratio of osmotic to gas pressure - .999.

TABLE XXVI.

0.2 WT. NORMAL SOLUTION AT 30°. CALCULATED GAS PRESSURE, 4.943.

Experiment 1. Cell K-6. Resistance of membrane, 122,222 ohms. Manometer, 32. Time setting up cell February 19, 1913. Barometer during final record: Max., 1.027; Min., .977. Initial pressure 6.943. Observed mean daily total pressures after cell became constant.

FINAL RECORD

28th day,	5.996 atms.	32nd day,	5.946 atms.	36th day,	5.941 atms.
29th "	5.958 "	33rd "	5.947 "	37th "	5.936 "
30th "	5.952 "	34th "	5.944 "	38th "	5.956 "
31st "	5.951 "	35th "	5.942 "	39th "	5.955 "

Mean of all daily pressures March 18 - 29 - 5.952 atms.
Mean barometric pressure March 18 - 29 - 1.006 atms.
Mean osmotic pressure March 18 - 29 - 4.946 atms.

TABLE XXVII.

Experiment 2. Cell O-6. Resistance of membrane, 110,000 ohms. Manometer, 32. Time setting up cell April 16, 1913. Barometer during final record: Max., 1.004; Min., .992. Initial pressure 7.409. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

29th day,	5.966 atms.	33rd day,	5.945 atms.	36th day,	5.952 atms.
30th "	5.922 "	34th "	5.967 "	37th "	5.915 "
31st "	5.916 "	35th "	5.939 "	38th "	5.907 "
32nd "	5.950 "				

Mean of all daily pressures May 14 - 23 - 5.938 atms.
Mean barometric pressure May 14 - 23 - 0.998 atms.
Mean osmotic pressure May 14 - 23 - 4.940 atms.
Mean osmotic pressure for experiments 1 and 2 - 4.943 atms.
Ratio of osmotic to gas pressure - 1.000.

TABLE XXVIII.

0.3 WT. NORMAL SOLUTION AT 30°. CALCULATED GAS PRESSURE, 7.415.

Experiment 1. Cell H-6. Resistance of membrane, 550,000 ohms. Manometer, 44. Time setting up cell January 24, 1913. Barometer during final record: Max., 1.009; Min., .987. Initial pressure 12.657. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

23rd day,	8.440 atms.	28th day,	8.456 atms.	32nd day,	8.435 atms.
24th "	8.429 "	29th "	8.474 "	33rd "	8.443 "
25th "	8.440 "	30th "	8.334 "	34th "	8.437 "
26th "	8.446 "	31st "	8.381 "	35th "	8.434 "
27th "	8.445 "				

Mean of all daily pressures Feb. 15 - 28 - 8.432 atms.
Mean barometric pressure Feb. 15 - 28 - 0.998 atms.
Mean osmotic pressure Feb. 15 - 28 - 7.434 atms.

TABLE XXIX.

Experiment 2. Cell G-6 Resistance of membrane, 366,666 ohms. Manometer, 37. Time setting up cell February 13, 1913. Barometer during final record: Max., 1.011; Min., .986. Initial pressure 9.196. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

20th day,	8.449 atms.	24th day,	8.429 atms.	27th day,	8.411 atms.
21st "	8.444 "	25th "	8.424 "	28th "	8.416 "
22nd "	8.435 "	26th "	8.419 "	29th "	8.413 "
23rd "	8.438 "				

Mean of all daily pressures Mar. 4- 14 - 8.428 atms.
Mean barometric pressure Mar. 4 - 14 - 1.002 atms.
Mean osmotic pressure Mar. 4 - 14 - 7.426 atms.
Mean osmotic pressure for experiments 1 and 2 - 7.430 atms.
Ratio of osmotic to gas pressure - 1.002.

TABLE XXX.

0.4 WT. NORMAL SOLUTION AT 30°. CALCULATED GAS PRESSURE, 9.886.

Experiment 1. Cell B-6. Resistance of membrane, 1,100,000 ohms. Manometer, 32. Time setting up cell January 17, 1913. Barometer during final record: Max., 1.018; Min., .982. Initial pressure 12.692. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

11th day,	10.880	atms.	15th day,	10.779	atms.	19th day,	10.749	atms.
12th "	10.883	"	16th "	10.782	"	20th "	10.753	"
13th "	10.855	"	17th "	10.773	"	21st "	10.738	"
14th "	10.818	"	18th "	10.719	"	22nd "	10.732	"

Mean of all daily pressures Jan. 27 - Feb. 7 - 10.800 atms.
Mean barometric pressure Jan. 27- Feb. 7 - 0.997 atms.
Mean osmotic pressure Jan. 27 - Feb. 7 - 9.803 atms.

TABLE XXXI.

Experiment 2. Cell Q-6. Resistance of membrane, 275,000 ohms. Manometer, 30. Time setting up cell January 20, 1913. Barometer during final record: Max., 1.018; Min., .982. Initial pressure 11.550. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

7th day,	10.990	atms.	12th day,	10.938	atms.	16th day,	10.928	atms.
8th "	10.964	"	13th "	10.944	"	17th "	10.919	"
9th "	10.968	"	14th "	10.949	"	18th "	10.923	"
10th "	10.967	"	15th "	10.911	"	19th "	10.919	"
11th "	10.953	"						

Mean of all daily pressures Jan. 26 - Feb. 7 - 10.946 atms.
Mean barometric pressure Jan. 26 - Feb. 7 - 0.997 atms.
Mean osmotic pressure Jan. 26 - Feb. 7 - 9.949 atms.

TABLE XXXII.

Experiment 3. Cell S-6. Resistance of membrane, 550,000 ohms. Manometer, 36. Time setting up cell April 16, 1913. Barometer during final record: Max., 1.000; Min., .989. Initial pressure 12.623. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

38th	day,	10.929 atms.	41st	day,	10.985 atms.	44th	day,	10.825 atms.
39th	"	10.891 "	42nd	"	10.817 "	45th	"	10.823 "
40th	"	10.966 "	43rd	"	10.812 "	46th	"	10.822 "

Mean of all daily pressures May 23 - 31 - 10.875 atms.

Mean barometric pressure May 23 - 31 - 0.993 atms.

Mean osmotic pressure May 23 - 31 - 9.882 atms.

Mean osmotic pressure for experiments 1 and 2 - 9.878 atms.

Ration of osmotic to gas pressure - .999.

TABLE XXXIII.

0.5 WT. NORMAL SOLUTION AT 30°. CALCULATED GAS PRESSURE, 12.358.

Experiment 1. Cell G-6. Resistance of membrane, 550,000 ohms. Manometer, 34. Time setting up cell March 19, 1913. Barometer during final record: Max., 1.016; Min., .985. Initial pressure 11.187. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

31st	day,	13.383	atms.	36th	day,	13.255	atms.	40th	day,	13.275	atms.
32nd	"	13.346	"	37th	"	13.220	"	41st	"	13.270	"
33rd	"	13.376	"	38th	"	13.209	"	42nd	"	13.307	"
34th	"	13.392	"	39th	"	13.336	"	43rd	"	13.319	"
35th	"	13.544	"								

Mean of all daily pressures April 18 - May 1	- 13.326 atms.
Mean barometric pressure April 18 - May 1	- 1.000 atms.
Mean osmotic pressure April 18 - May 1	- 12.326 atms.

TABLE XXXIV.

Experiment 2. Cell C-6. Resistance of membrane, 275,000 ohms. Manometer, 37. Time setting up cell April 16, 1913. Barometer during final record: Max., 1.008; Min., .993. Initial pressure 14.598. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

16th	day,	13.406	atms.	21st	day,	13.361	atms.	25th	day,	13.530	atms.
17th	"	13.321	"	22nd	"	13.437	"	26th	"	13.385	"
18th	"	13.251	"	23rd	"	13.423	"	27th	"	13.367	"
19th	"	13.311	"	24th	"	13.400	"	28th	"	13.279	"
20th	"	13.272	"								

Mean of all daily pressures May 1 - 14	- 13.365 atms.
Mean barometric pressure May 1 - 14	- 1.001 atms.
Mean osmotic pressure May 1 - 14	- 12.364 atms.
Mean osmotic pressure for experiments 1 and 2	- 12.345 atms.
Ratio of osmotic to gas pressure	- .998.

TABLE XXXV.

0.1 WT. NORMAL SOLUTION AT 40°. CALCULATED GAS PRESSURE, 2.553.

Experiment 1. Cell S-6. Resistance of membrane 275,000 ohms. Manometer, 61. Time setting up cell March 14, 1914. Barometer during final record: Max., 1.004; Min., .986. Initial pressure 3.160. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

35th day,	3.563 atms.	37th day,	3.550 atms.	39th day,	3.551 atms.
36th "	3.560 "	38th "	3.544 "		

Mean of all daily pressures April 17 - 21	- 3.554 atms.
Mean barometric pressure April 17 - 21	- 0.997 atms.
Mean osmotic pressure April 17 - 21	- 2.557 atms.
Ratio of osmotic to gas pressure	- 1.001.

TABLE XXXVI.

0.2 WT. NORMAL SOLUTION AT 40°. CALCULATED GAS PRESSURE, 5.107.

Experiment 1. Cell 0-6. Resistance of membrane, 366,666 ohms. Manometer, 37. Time setting up cell March 16, 1914. Barometer during final record: Max., 1.006; Min., .985. Initial pressure 6.327. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

22nd day,	6.157 atms.	26th day,	6.094 atms.	29th day,	6.070 atms.
23rd "	6.143 "	27th "	6.095 "	30th "	6.082 "
24th "	6.116 "	28th "	6.078 "	31st "	6.077 "
25th "	6.093 "				

Mean of all daily pressures April 6 - 15 - 6.101 atms.
Mean barometric pressure April 6 - 15 - 0.998 atms.
Mean osmotic pressure April 6 - 15 - 5.103 atms.

TABLE XXXVII.

Experiment 2. Cell Q-6. Resistance of membrane, 157.142 ohms. Manometer, 40. Time setting up cell March 16, 1914. Barometer during final record: Max., 1.011; Min., .985. Initial pressure 5.992. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

12th day,	6.155 atms.	17th day,	6.091 atms.	21st day,	6.122 atms.
13th "	6.148 "	18th "	6.078 "	22nd "	6.111 "
14th "	6.134 "	19th "	6.110 "	23rd "	6.091 "
15th "	6.132 "	20th "	6.105 "	24th "	6.056 "
16th "	6.101 "				

Mean of all daily pressures Mar. 27 - April 8 - 6.110 atms.
Mean barometric pressure Mar. 27, - April 8 - 0.999 atms.
Mean osmotic pressure Mar. 27 - April 8 - 5.111 atms.
Mean osmotic pressure for experiments 1 and 2 - 5.107 atms.
Ratio of osmotic to gas pressure - 1.000.

TABLE XXXVIII.

0.3 WT. NORMAL SOLUTION AT 40°. CALCULATED GAS PRESSURE, 7.660.

Experiment 1. Cell C-6. Resistance of membrane, 110,000 ohms. Manometer, 44. Time setting up cell December 3, 1913. Barometer during final record: Max., 1.017; Min., .988. Initial pressure 8.211. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

40th day,	8.606 atms.	43rd day,	8.671 atms.	46th day,	8.715 atms.
41st "	8.640 "	44th "	8.652 "	47th "	8.719 "
42nd "	8.677 "	45th "	8.644 "	48th "	8.668 "

Mean of all daily pressures Jan. 11 - 19 - 8.663 atms.
Mean barometric pressure Jan. 11 - 19 - 0.999 atms.
Mean osmotic pressure Jan. 11 - 19 - 7.664 atms.

TABLE XXXIX.

Experiment 2. Cell T-6. Resistance of membrane, 84,615 ohms. Manometer, 43. Time setting up cell April 21, 1914. Barometer during final record: Max., 1.002; Min., .982. Initial pressure 11.428. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

10th day,	8.727 atms.	13th day,	8.659 atms.	15th day,	8.609 atms.
11th "	8.723 "	14th "	8.638 "	16th "	8.592 "
12th "	8.665 "				

Mean of all daily pressures April 30 - May 6 - 8.659 atms.
Mean barometric pressure April 30 - May 6 - 0.995 atms.
Mean osmotic pressure April 30 - May 6 - 7.664 atms.
Mean osmotic pressure for experiments 1 and 2 - 7.664 atms.
Ratio of osmotic to gas pressure - 1.000.

TABLE XL.

0.4 WT. NORMAL SOLUTION AT 40°. CALCULATED GAS PRESSURE, 10.213.

Experiment 1. Cell F-6. Resistance of membrane, 55,000 ohms. Manometer, 37. Time setting up cell December 17, 1913. Barometer during final record: Max., 1.005; Min., .982. Initial pressure 11.909. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

15th day,	11.249	atms.	19th day,	11.163	atms.	22nd day,	11.168	atms.
16th "	11.227	"	20th "	11.123	"	23rd "	11.136	"
17th "	11.169	"	21st "	11.158	"	24th "	11.256	"
18th "	11.291	"						

Mean of all daily pressures Dec. 31 - Jan. 9 - 11.194 atms.
Mean barometric pressure Dec. 31 - Jan. 9 - 0.993 atms.
Mean osmotic pressure Dec. 31 - Jan. 9 - 10.201 atms.

TABLE XLI.

Experiment 2. Cell C-6. Resistance of membrane, 110,000 ohms. Manometer, 41. Time setting up cell February 7, 1914. Barometer during final record: Max., 1.011; Min., .985. Initial pressure 18.856. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

53rd day,	11.287	atms.	56th day,	11.238	atms.	59th day,	11.215	atms.
54th "	11.279	"	57th "	11.237	"	60th "	11.188	"
55th "	11.241	"	58th "	11.221	"	61st "	11.150	"

Mean of all daily pressures Mar. 31 - Apr. 8 - 11.228 atms.
Mean barometric pressure Mar. 31 - Apr. 8 - 0.998 atms.
Mean osmotic pressure Mar. 31 - Apr. 8 - 10.230 atms.
Mean osmotic pressure for experiments 1 and 2 - 10.215 atms.
Ratio of osmotic to gas pressure - 1.000.

TABLE XLII.

0.5 WT. NORMAL SOLUTION AT 40°. CALCULATED GAS PRESSURE, 12.767.

Experiment 1. Cell K-6. Resistance of membrane, 57,894 ohms. Manometer, 41. Time setting up cell December 16, 1913. Barometer during final record: Max., 1.017; Min., .987. Initial pressure 13.351. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

26th day,	13.669	atms.	30th day,	13.858	atms.	33rd day,	13.773	atms.
27th "	13.601	"	31st "	13.866	"	34th "	13.874	"
28th "	13.668	"	32nd "	13.853	"	35th "	13.852	"
29th "	13.887	"						

Mean of all daily pressures Jan. 10 - 19 - 13.790 atms.
Mean barometric pressure Jan. 10 - 19 - 0.998 atms.
Mean osmotic pressure Jan. 10- 19 - 12.792 atms.

TABLE XLIII.

Experiment 2. Cell F-6. Resistance of membrane 55,000 ohms. Manometer, 30. Time setting up cell February 7, 1914. Barometer during final record: Max., 1.006; Min., .988. Initial pressure 19.623. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

28th day,	13.755	atms.	32nd day,	13.830	atms.	36th day,	13.832	atms.
29th "	13.775	"	33rd "	13.844	"	37th "	13.842	"
30th "	13.762	"	34th "	13.830	"	38th "	13.816	"
31st "	13.812	"	35th "	13.853	"			

Mean of all daily pressures Mar. 6 - 16 - 13.814 atms.
Mean barometric pressure Mar. 6 - 16 - 0.998 atms.
Mean osmotic pressure Mar. 6 - 16 - 12.816 atms.
Mean osmotic pressure for experiments 1 and 2 - 12.804 atms.
Ratio of osmotic to gas pressure - 1.002.

TABLE XLIV.

0.6 WT. NORMAL SOLUTION AT 40°. CALCULATED GAS PRESSURE, 15.320.

Experiment 1. Cell B-6. Resistance of membrane 91,666 ohms. Manometer, 42. Time setting up cell January 9, 1914. Barometer during final record: Max., 1.019; Min., .977. Initial pressure 15.062. Observed mean daily total pressures after cell became constant.

FINAL RECORD.

26th day,	16.457	atms.	30th day,	16.236	atms.	34th day,	16.331	atms.
27th "	16.290	"	31st "	16.270	"	35th "	16.253	"
28th "	16.290	"	32nd "	16.456	"	36th "	16.328	"
29th "	16.285	"	33rd "	13.364	"			

Mean of all daily pressures Feb. 3 - 13 - 16.324 atms.

Mean barometric pressure Feb. 3 - 13 - 1.005 atms.

Mean osmotic pressure Feb. 3 - 13 - 15.319 atms.

Ratio of osmotic to gas pressure - 1.000.

TABLE XLV.

WEIGHT-NORMAL CONCENTRATION.

	0.1	0.2	0.3	0.4	0.5	0.6
TEMP.	MEAN OSMOTIC PRESSURE IN ATMOSPHERES.					
10°	2.314	4.610	6.940	9.208	11.614	......
20°	2.394	4.780	7.181	9.569	11.960	......
30°	2.469	4.943	7.430	9.878	12.345	......
40°	2.557	5.107	7.664	10.215	12.804	15.219

TABLE XLVI.

WEIGHT-NORMAL CONCENTRATION.

	0.1	0.2	0.3	0.4	0.5	0.6
TEMP.	RATIO OF OSMOTIC TO GAS PRESSURE.					
10°	1.002	.998	1.002	.997	1.006	......
20°	1.001	1.000	1.001	1.001	1.001	......
30°	.999	1.000	1.002	.999	.998	......
40°	1.001	1.000	1.000	1.000	1.002	1.000

DISCUSSION OF MEASUREMENTS.

Tables V to XLIV give a somewhat detailed account of each experiment.

Table XLV gives for each of the concentrations with which it was possible to work the osmotic pressures which have been found at 10°, 20°, 30° and 40°.

Table XLVI shows the ratio of the osmotic pressures given in Table XLV to the calculated gas pressures of the solute.

CONCLUSIONS.

The conclusions which can be drawn from Table XLVI are:

1. In all solutions of mannite from 0.1 to 0.6 weight-normal the ratio of the observed osmotic to the estimated gas pressure of the solute is constant and unity for each concentration at 10°, 20°, 30° and 40°. This proves, therefore, that between the specified limits of concentration and temperature the osmotic pressure of mannite solutions obeys both the laws of Gay-Lussac and of Boyle for gases.
2. If a substance exhibits a normal molecular depression of the freezing point it appears probable from the experience with mannite that the ratio of osmotic to gas pressures will be unity at all temperatures. In other words that the osmotic pressure of its solutions will obey the laws of Gay-Lussac and of Boyle for gases.
3. By use of the weight-normal system of making up solutions the

equation $p\ (v - b) = K\ T$, in which we may be supposed automatically to correct for the b, holds not only for dilute but also for more concentrated solutions. Stated in another way the equation of Van't Hoff _for very dilute solutions_ ($pv = KT$) appears to hold also for concentrated solutions of mannite if we allow the v to signify not the volume of the solution but that of the free solvent.

The osmotic pressure of solutions of mannite will be next determined at 0° also at temperatures as much above 40° as it is practicable to work. This will be done in order to ascertain whether substances exhibiting normal depressions of the freezing points may be expected to exhibit osmotic pressures conforming under all circumstances to the gas laws.

BIOGRAPHY.

Edwin Louis Frederick was born March 17, 1891, at Baltimore, Md. His early education was obtained at the public schools of that city, graduating from The Baltimore City College in the spring of 1907. In the fall of that year he entered The Johns Hopkins University, Baltimore, Md., and graduated in 1911, receiving the Degree of Bachelor of Arts. October, 1911 he entered the graduate department of this University, majoring in Chemistry, with Physical Chemistry and Applied Geology, respectively, as his first and second subordinate subjects.

In 1911 - 1912 he was laboratory assistant, while in 1912 - 1913 he held a Hopkins scholarship and in June, 1913 was appointed a University Fellow for the year 1913 - 1914.